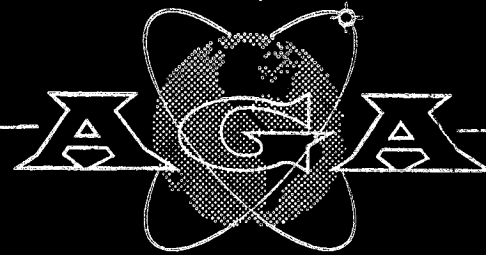


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Aero Geo Astro Corporation
Alexandria, Virginia

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Progress Report

Missile Monitoring Program

1 April 1961

Office of Naval Research

Contract 3163 (00)

AERO GEO ASTRO
CORPORATION
ALEXANDRIA, VIRGINIA

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MISSILE MONITORING PROGRAM

1 April 1961

Prepared by

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Prepared under Office of Naval Research Contract 3163(00)

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TABLE OF CONTENTS

1.	Introduction	2
2.	System	2
3.	Data	3
4.	Pacific Missile Range Tests	3
5.	Atlantic Missile Range Tests	4
6.	Summary	6

TABLE OF FIGURES

1.	Test 1053: Trajectory of Discoverer Launched from PMR	7
2.	Test 1053: Discoverer Launch: Patuxent Radar Site	8
3.	Test 3504: Trajectory Atlas Launched from AMR	9
4.	Test 3504: Atlas Launch: Patuxent Radar Site	10
5.	Test 412: Polaris Launch: Boulder Radar Site	11
6.	Test 826: Bluescout Launch: Boulder Radar Site	12
7.	Test 5101: Redstone Launch: Boulder Radar Site	13
8.	Test 5101: Redstone Launch: Patuxent Radar Site	14
9.	Test 413: Polaris Launch: Boulder Radar Site	15
10.	Test 815: Polaris Launch: Boulder Radar Site	16
11.	Test 816: Pershing Launch: Boulder Radar Site	17

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1. INTRODUCTION

This report discusses VLF radar detection of ballistic missile launches at Atlantic Missile Range and Pacific Missile Range during the period 24 January to 15 March, 1961. The two Aero Geo Astro stations, used previously for monitoring the recent French nuclear test and for the detection of large meteor showers¹, were modified to enable them to look at launches from both coasts. The radar at Boulder, Colorado, has about a 1600-mile range to AMR launches and about a 900-mile range to PMR launches, while the Patuxent, Maryland, station is used for medium-range detection (700 miles) of AMR launches and long-range detection (2500 miles) of PMR launches. In general, the results confirm previous detection of large missile launches obtained from Corona, California. These results show that the detection usually begins shortly before the missile penetrates the D layer, with some indication of even lower detection. In general, the reflection lasts for many minutes.

In addition to monitoring the large missile launches, a number of smaller missiles (primarily Polaris) have been monitored. These missiles have not been previously detected by VLF radar. The radar frequency limits have been raised to include NSS (22.3 kc) whereas previous detections covered the frequency range from 14 to 18 kc. The measurements are not precise enough to determine any small frequency dependence of the scatter over this frequency range; however, no gross effects have been noticed.

2. SYSTEM

The bi-static radar systems are described in some detail in a previous report¹. Simplified operation is as follows:

The VLF pulse from a station (NPG or NSS) is picked up on a reference antenna and delayed in a sonic delay line system an amount equal to the round-trip propagation time to the target area. This delayed pulse is used as the reference signal for the R-F correlator. The backscatter energy is picked up on a loop antenna (in the case of AMR launches, the Patuxent station uses a loop monopole combination giving a cardioid pattern), amplified and fed to the correlator. The output of the correlator is recorded on a paper chart recorder. Both the delayed reference channel and the signal channel are gated off for the duration of the station's transmitted pulse. This gating, or blanking, prevents the system from correlating on that portion of the direct transmit pulse which is received on the signal antenna. The leading and tailing edge of the pulse are quite long (a few milliseconds) so that considerable care must be taken in order to completely blank out this leakage signal. For medium-range operation (such as Patuxent to AMR), the tail portion of the pulse cannot be blanked as this occurs during reception of the target echo. This undesirable station leakage is greatly reduced by centering the null of the cardioid antenna pattern on

1

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the station. It is planned to switch the operation of the VLF RADAR station at Patuxent from NSS to NAA (Cutler, Maine) when NAA goes on a regular schedule. The operation and sensitivity of the Patuxent station is expected to improve when full use can be made of NAA.

3. DATA

All of the tests monitored at both sites between 24 January 1961 and 15 March 1961 will be discussed in this section. A considerable number of tests, during this period, were not monitored due to down time while changing the stations over from nuclear detection to missile monitoring.

For each test, the effective radar cross sections have been calculated using the VLF radar equation¹. In all of the calculations, the attenuation coefficient was assumed to be 2 db per thousand kilometers. It is known, however, that this coefficient varies from day to night and under other conditions, so that the calculated cross sections may be a few db in error.

Field intensity measurements of the VLF stations were made at Boulder, Colorado, during the test intervals so that times of abnormal attenuation are recorded. In the future, field intensity measurements will be made simultaneously at Patuxent, Maryland; Boulder, Colorado; and Corona, California so that the attenuation constant can be determined for each test. The measured cross sections (σ) have ranged between 10^6 and 10^7 square meters which compares favorably with measurements made at the 200-mile range earlier at Corona. Radars are calibrated by using both CW signal and typical pulse code signals. The calibration is generally indicated in db relative to a signal field intensity of $1 \mu\text{v/m}$, (i.e., a -20db calibration indicates that a CW signal of a $.1 \mu\text{v/m}$ produced a deflection of one division.) Code transmission requires higher signal field intensity than CW for the same deflection due to the lower duty cycle. At the Boulder site, this factor is typically about 17 db.

Many other precautions are taken in and around test time to minimize the possibility of false target indications. Meteor shower records are examined in order to determine if any have occurred near the test time. The preliminary reports of solar activity by the High Altitude Observatory, University of Colorado, are also referred to for various geophysical phenomena, such as aurora, solar radio noise bursts, magnetic storms, sudden enhancements and sudden cosmic noise absorption. Attempts will also be made to correlate apparent drifts in the reflection center with high altitude wind measurements, as they become available, for the particular tests.

4. PACIFIC MISSILE RANGE TESTS

Test No. 1053. This was a Discoverer launch on 18 February 1961. The trajectory is shown in Figure 1. This launch was detected at the Patuxent

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site using NSS as the source. The signature is shown in Figure 2. The station was off the air from a few minutes before T_0 to about $T_0 + 2$ minutes. The signature appears to begin at about $T_0 + 2-1/2$ minutes and reaches a first peak at around 3 minutes. The calculated cross section for this first portion is about 2×10^6 square meters. There is a larger rise beginning at about +4 minutes. This time coincides closely to the Agena ignition; however, this is most probably a coincidence. The cross section corresponding to this peak is about 6×10^7 square meters. Only one channel was available at this time so that the decreasing signal beginning at about +7 minutes does not necessarily indicate the decay rate of the perturbation but could represent a drift in the reflecting area.

5. ATLANTIC MISSILE RANGE TESTS

Test No. 3504: This was an Atlas launch on 24 January 1961. The trajectory is shown in Figure 3. At the time of this test, the loop monopole nulling system was not in use at Patuxent; therefore, there was quite a large residual correlated output due to the slow tail-off of the pulse. The portion of the signature around T-3 minutes, as shown in Figure 4, shows the residual offset due to the low duty cycle beeping transmission. From about -1 minute to +1 minute, the station is off the air. At about +1 minute, the station comes on its regular code transmission and a larger offset occurs, believed primarily due to the higher duty cycle. Just prior to 2-1/2 minutes, there is a sharp change in signal level. This is attributed to the missile launch. It appears in this case that the scatter signal is essentially out of phase with the pulse leakage signal. The missile would be about at 80 kilometers altitude at this time. The change in signal level about 20 seconds earlier might possibly be associated with the missile. This occurs at an altitude of about 50 kilometers. The dashed lines in the signature are for portions of the time when the station either went off the air for a short time, or reduced duty cycle radically. This shows the probable signal level for a constant duty cycle transmission. The cross section was calculated to be about 3×10^6 square meters.

Test No. 412: This was a Polaris launched at 1819:09 GMT on 1 March 1961. The field intensity of NPG, as measured at Boulder during this time, was about 3.7 mv/m. The signature is shown in Figure 5. It is noted that there is a fairly sharp rise in the signal level shortly before $T_0 + 1-1/2$ minutes. The trajectory for this test is not available as of this writing; however, assuming a typical Polaris trajectory, this places the missile at about 60 kilometer altitude at $T_0 + 1-1/2$ minutes. The calculated backscatter cross section is 8×10^6 square meters.

Test No. 826: This was a Bluescout launch on 3 March 1961. The field intensity of NPG at Boulder was 3.3 mv/m. The onset of the signature, as shown in Figure 6, apparently begins at about +80 seconds with the further increase at about 2 minutes. The missile altitudes corresponding to these times are not known at present. The calculated cross section is 4×10^6 square meters..

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Test No. 5101: This was a Redstone launch at 0230 GMT on 9 March 1961. It was nighttime over the propagation path thus giving a higher field intensity reading at Boulder for NPG; i.e., 4.8 mv/m. The signature is shown in Figure 7. There is a possible onset of signal at about 1-1/2 minutes but more probably, the signature begins just prior to +2 minutes. The peak of the signature occurs at about 2-1/4 minutes. The trajectory of this launch is not available; however, for a typical Redstone launch, the missile would be at about 57 kilometers at T_0 +2-1/4 minutes. The calculated cross section is 2×10^6 square meters.

This launch was also monitored at Patuxent using NSS as a source. The signature is shown in Figure 8. There is no indication of detection immediately or shortly after launch; however, with only one channel available, most of the signature return could have been in the quadrature channel. It appears that the ionized cloud, or perturbation, may have drifted to allow the signature to begin to appear in this channel at about +5 minutes. The signal reached a peak in this channel at about +15 minutes and then began to decrease. This decrease of signal could be due to decay of the perturbation, but it could also be a slow drift in range.

Test No. 413: This was a Polaris launch at AMR on 9 March 1961 at 1850:11 GMT. The NPG field intensity was measured as 2.9 mv/m at Boulder. This is considerably below the usual field intensity measured at Boulder, and could indicate an increase in the attenuation factor. A geomagnetic storm also occurred during this period. The increased attenuation rate may have been related to this storm in some fashion although the storm did not produce any noticeable scatter effects during the monitoring time. The results at Boulder are considered negative for this test. If the attenuation rate was the usual 2 db per 1000 KM, the cross section would have been below 10^6 square meters; however, it is believed that the negative result is due to a higher than normal attenuation rate along the VLF path.

There is an indication of a detection on this launch at the Patuxent site using NSS as the source. The signature is shown in Figure 9. The signal was somewhat out of a good null as is noticed from the signature previous to T_0 . At about T_0 , the station went off code to their regular transmission of "beeps", or dashes with long spacing between them. This transmission is of a constant duty cycle but with considerably lower average power. This portion of the record is shown expanded in the figure. The signature apparently begins at about 80 seconds and reaches a peak at around 90 seconds. For a typical Polaris launch, these times correspond to approximately 45 and 60 kilometer altitude. When the station comes back onto its regular code transmission, it is noted that the deviation from zero is greater than it was previous to the test.

Test No. 815: This was a Polaris missile launched on 15 March 1961. The signature obtained at Boulder is shown in Figure 10. There is some indication of scatter beginning at about +1-1/4 minutes. There is a larger signal change occurring in the region of 13 to 14 minutes after T_0 . Trajectory information is not available on this launch at present so that little analysis has been done.

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Test No. 816: This test, which likewise has not been analyzed in any detail, was a Pershing launch on 16 March 1961. Pershing missiles typically burn out at about +70 seconds. It is noted from the signature shown in Figure 11 that there is no indication of scatter during the burn period. There is some slight indication of scatter beyond this period, particularly around +5 minutes.

6. SUMMARY

In summary, it may be stated that there is strong evidence that the smaller missiles, such as Polaris, produce ionized trails and/or ionospheric perturbations which may be detected by VLF backscatter systems. The scatter cross sections generally ranged between 10^6 and 10^7 square meters.

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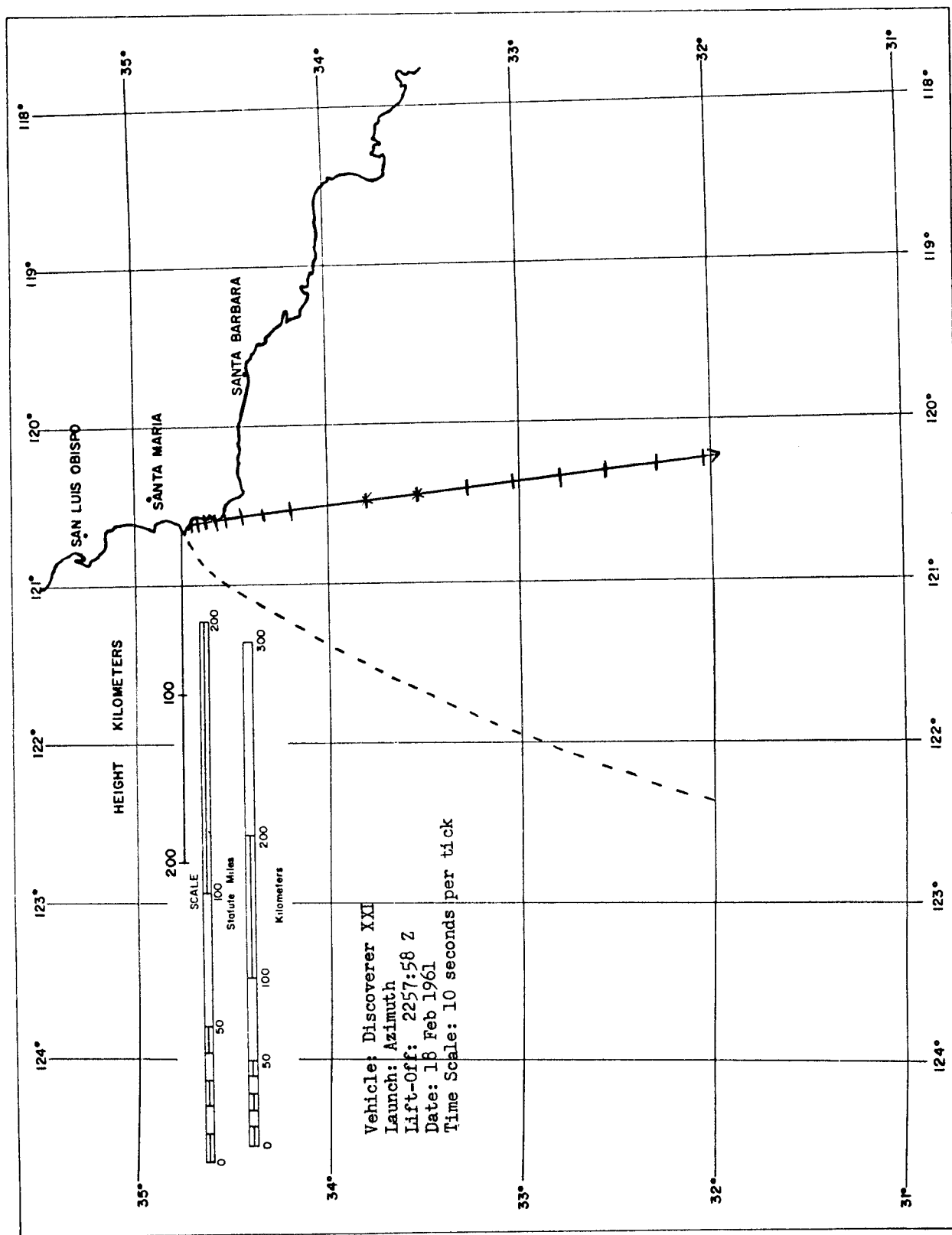


Figure 1. Test No. 1053: Trajectory of Discoverer launched from PMR.

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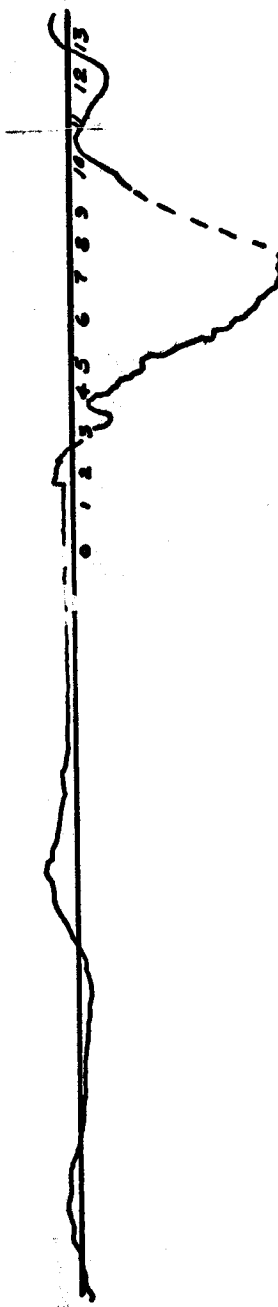


Figure 2. Test No. 1053, Discoverer Launch, Patuxent Radar Site.

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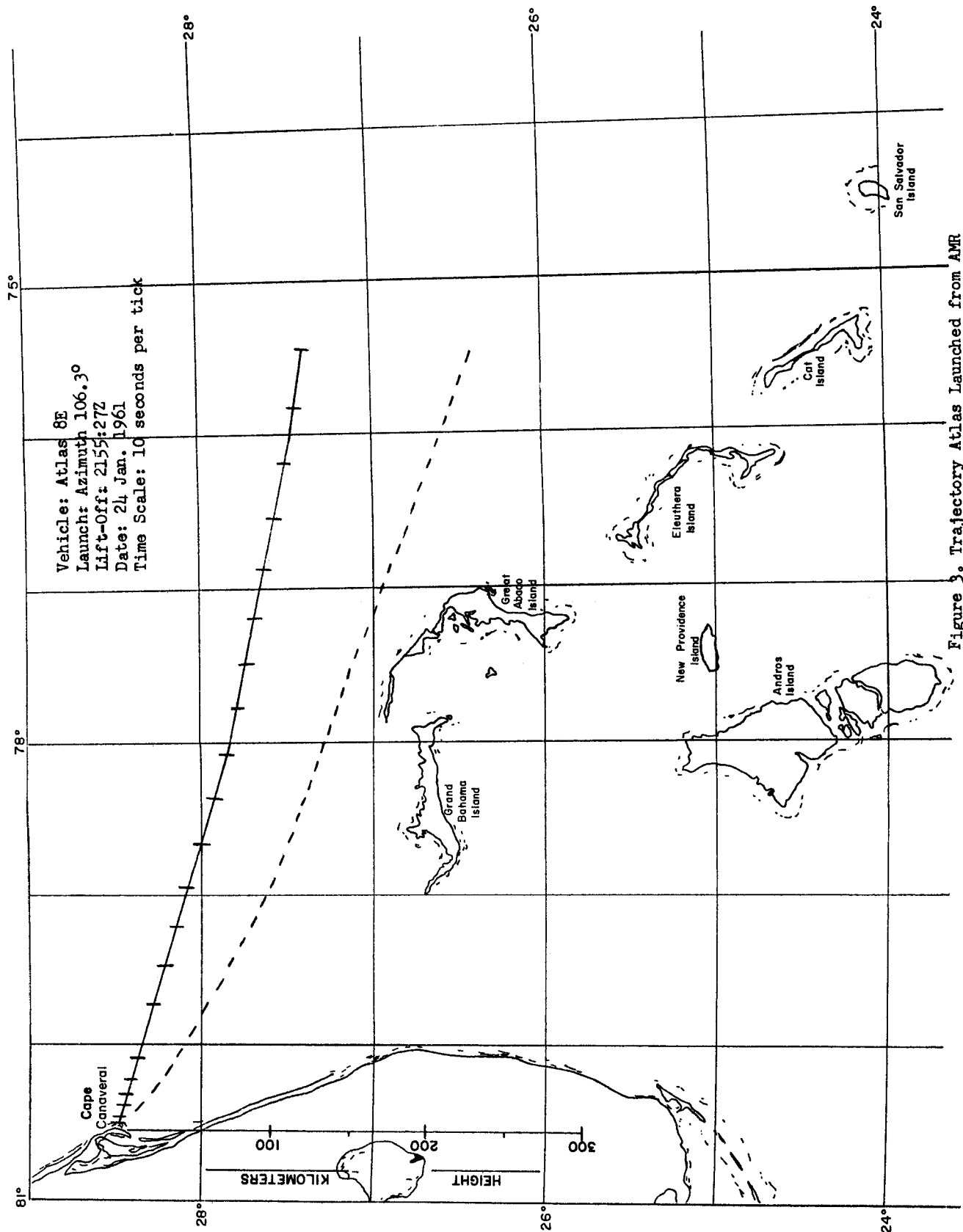


Figure 3. Trajectory Atlas Launched from AMR

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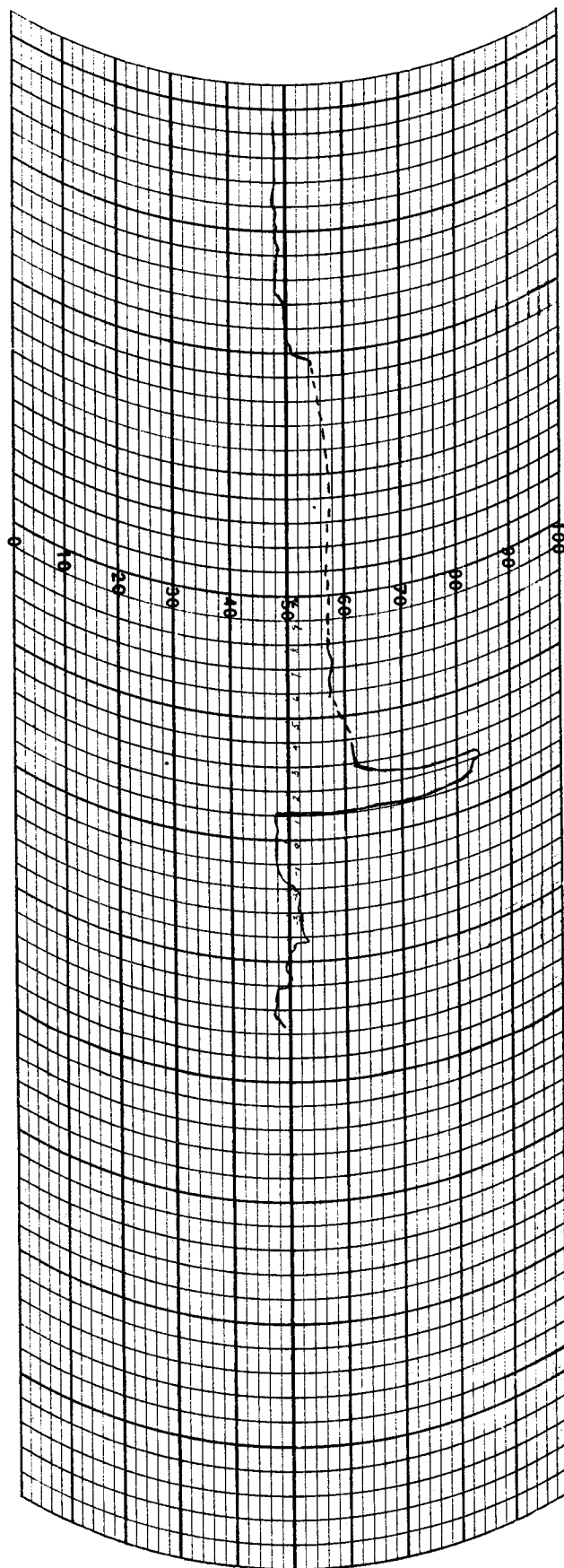


Figure 4. Test No. 3504: Atlas Launch: Patuxent Radar Site

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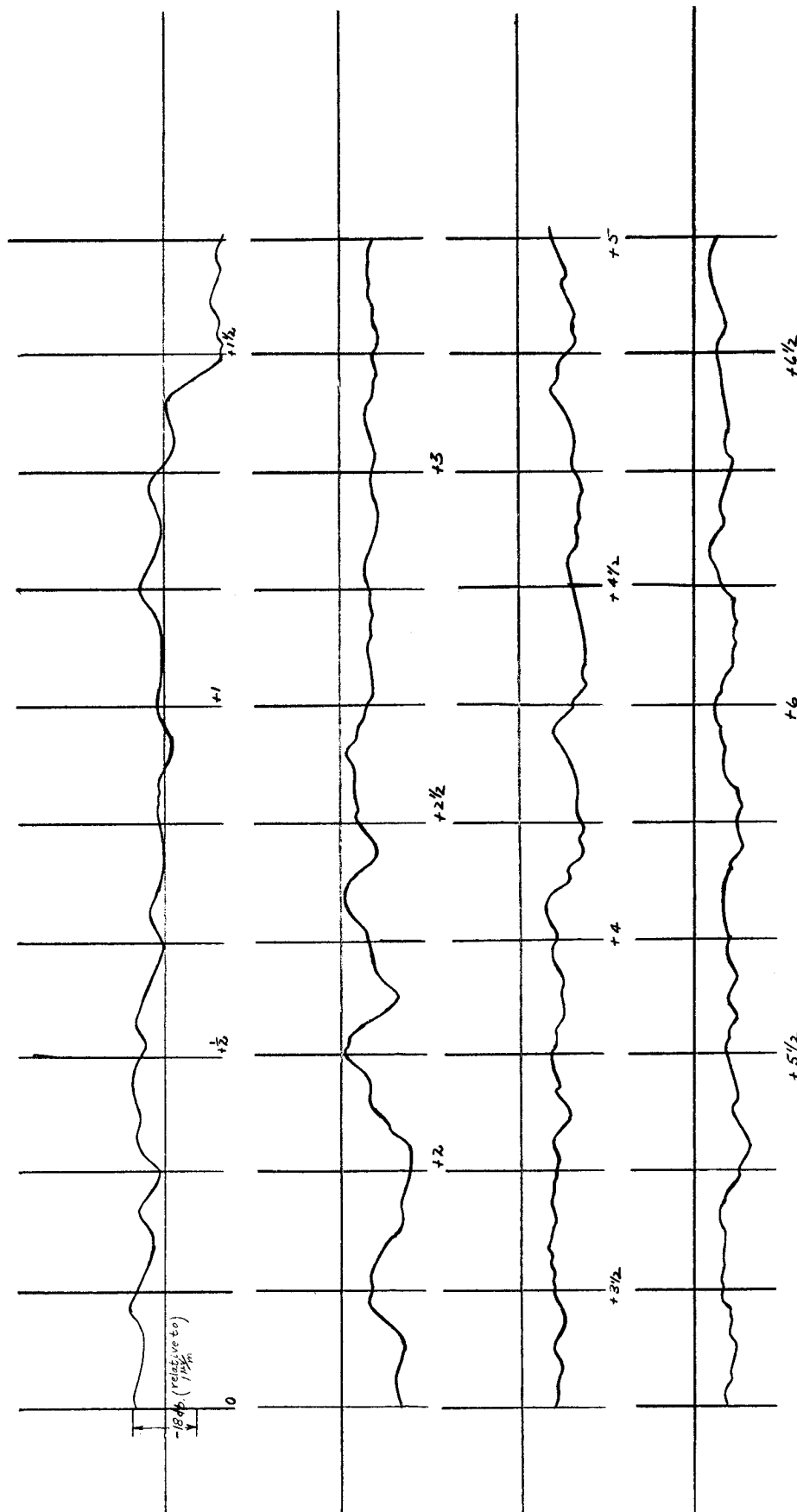


Figure 5. Test No. 412. Polaris Launch: Boulder Radar Site.

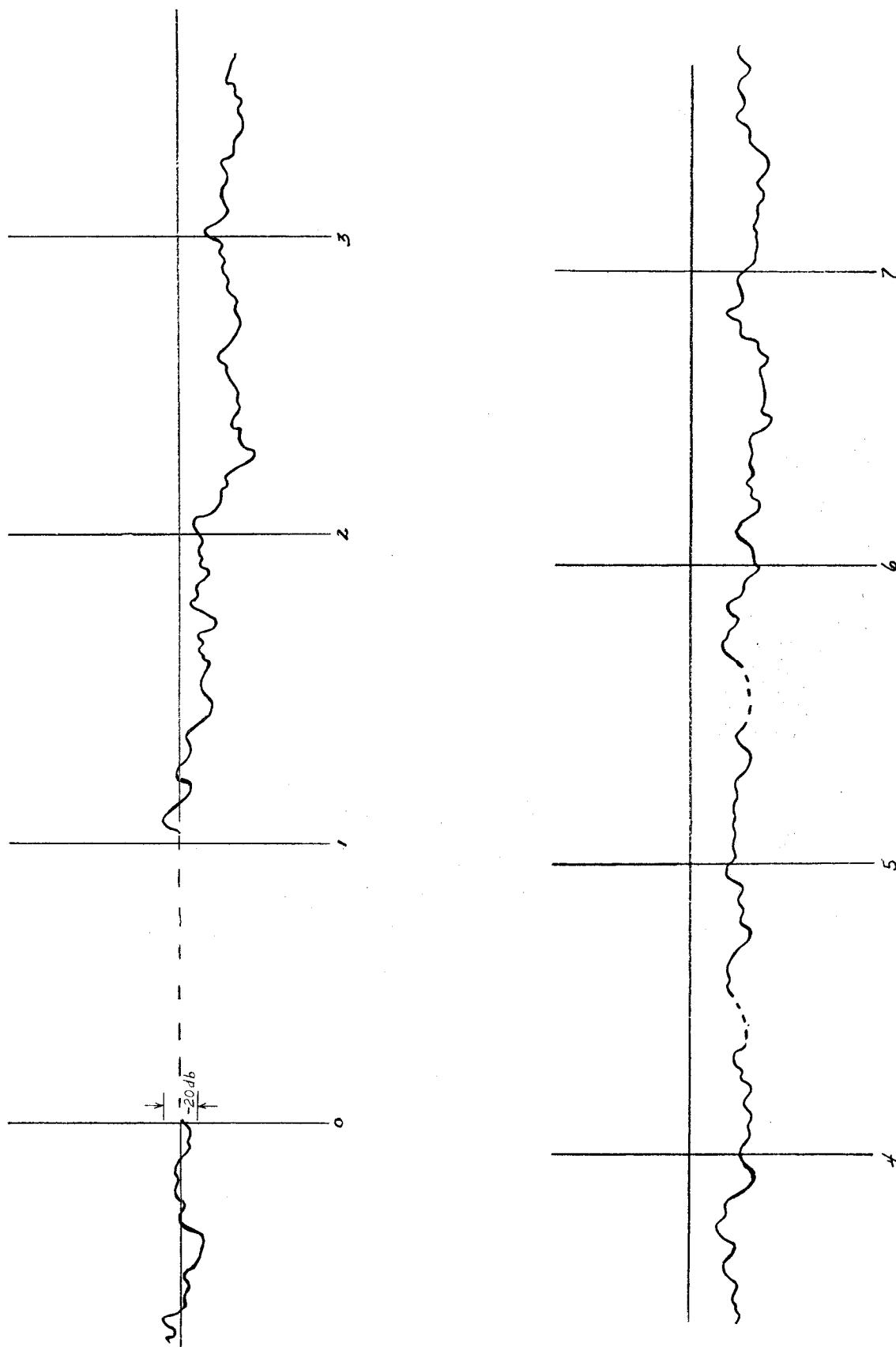
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Figure 6. Test No. 826. Bluescout Launch: Boulder Radar Site

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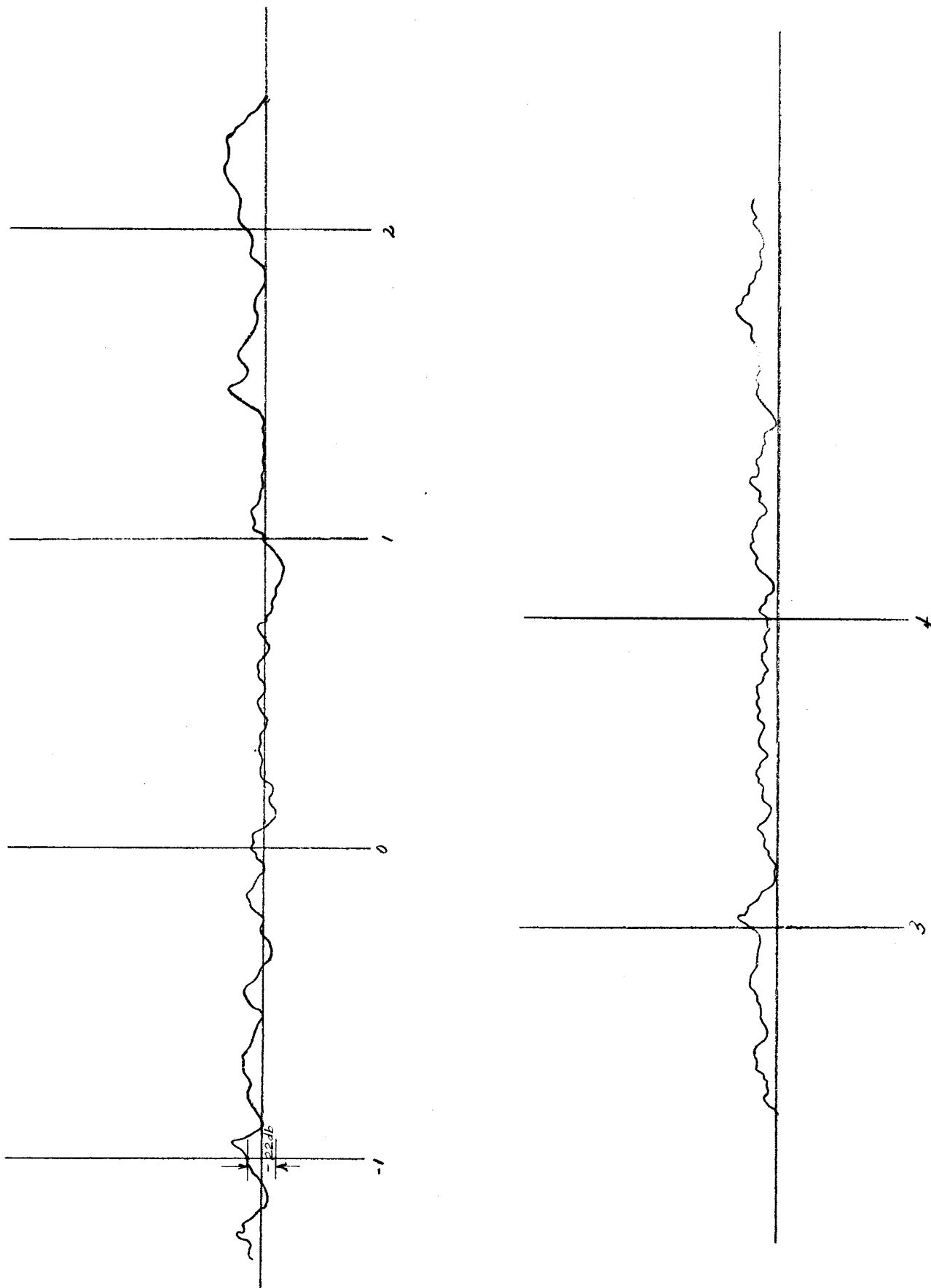


Figure 7. Test No. 5101. Redstone Launch: Boulder Radar Site

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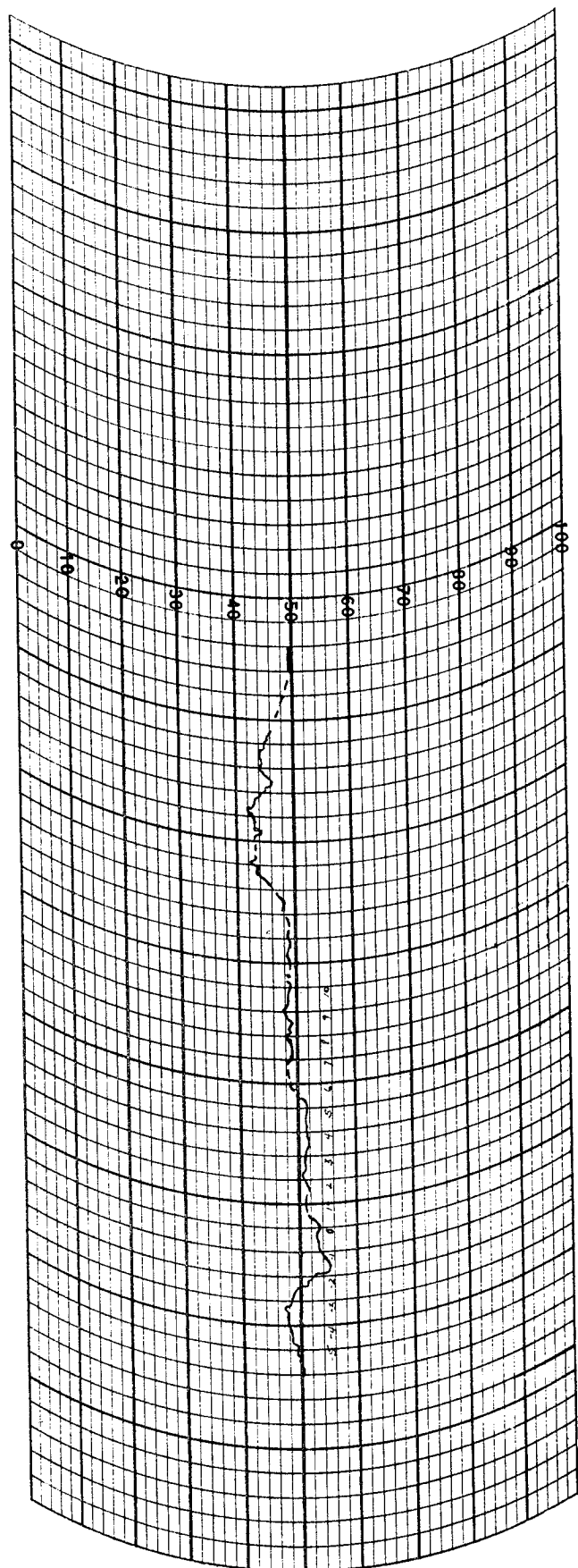


Figure 8. Test No. 5101. Redstone Launch: Patuxent Radar Site

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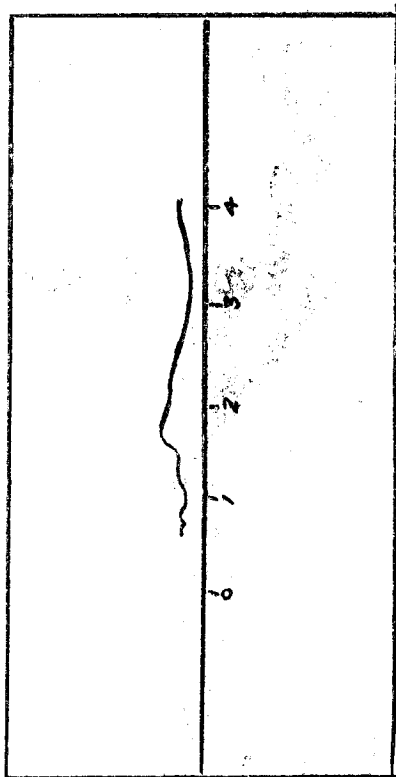
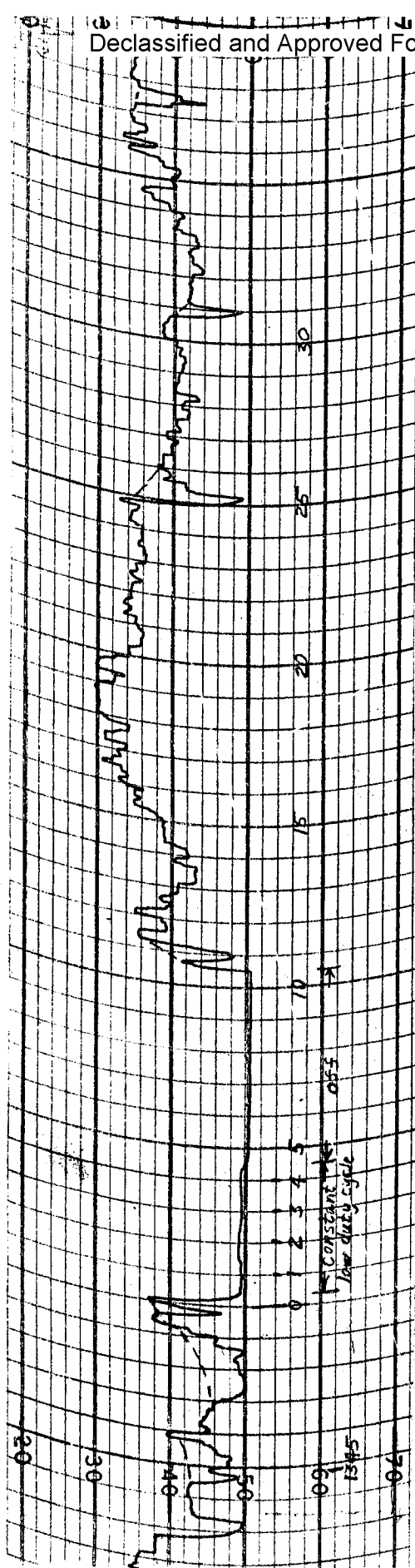


Figure 9. Test No. 413, Polaris Launch, Patuxent Site.

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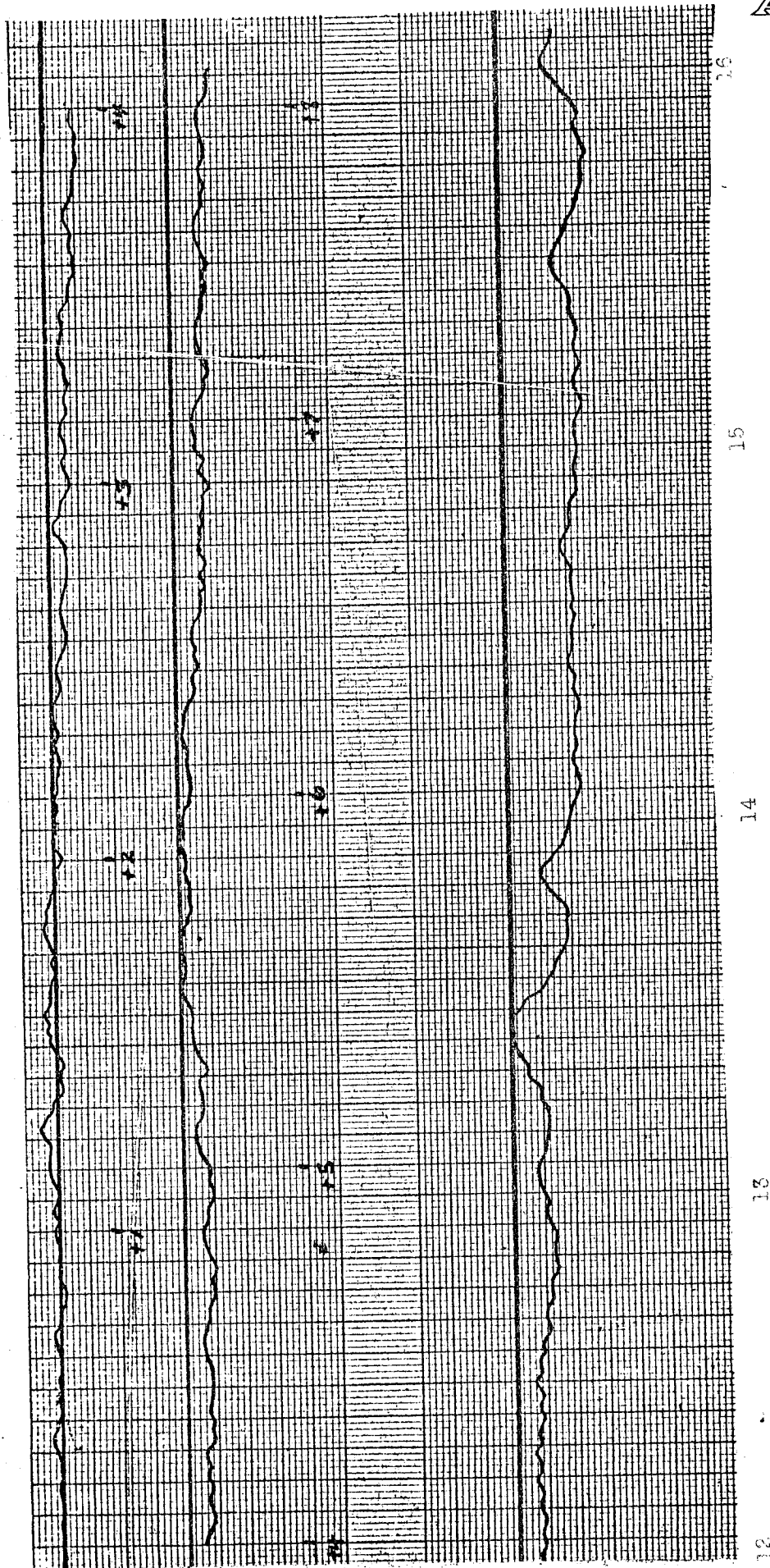


Figure 10. Test No. 815, Polaris Launch, Boulder Radar Site.

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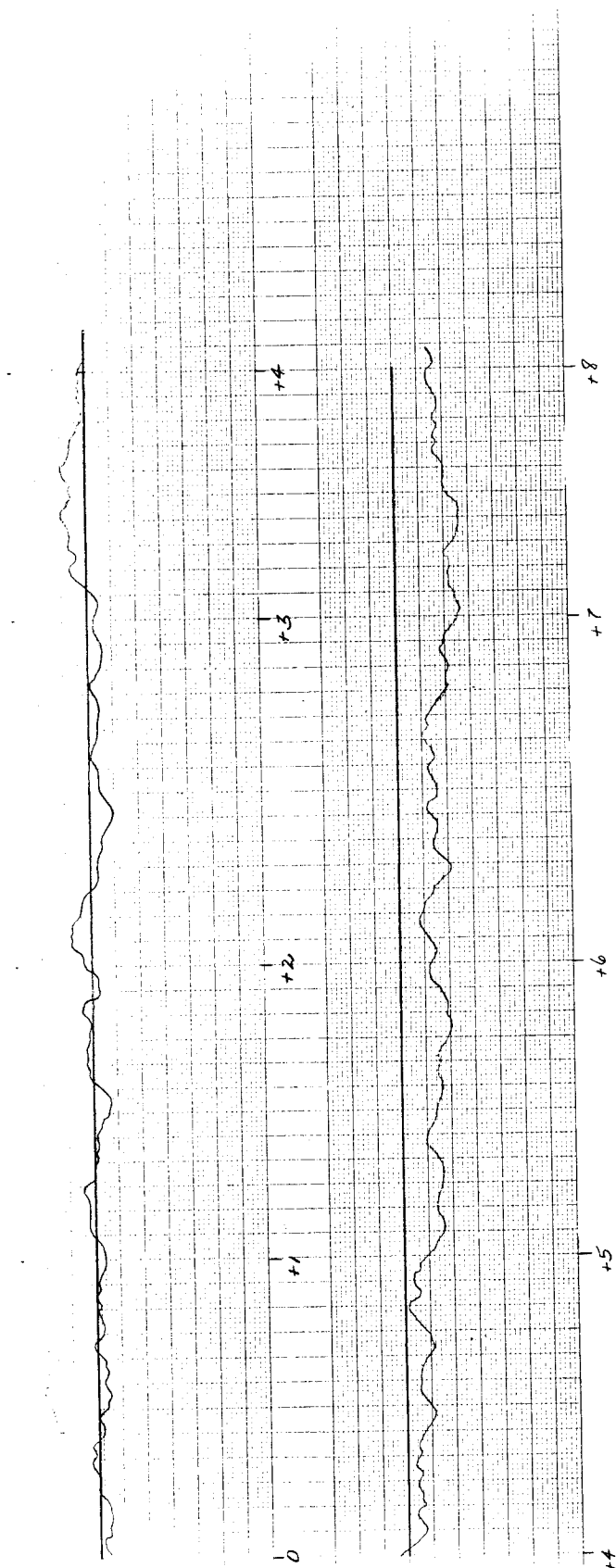


Figure 11. Test No. 816. Pershing Launch: Boulder Radar Site

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